Experimental modeling of the effect of the chemical action on the mechanical behavior of clays

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ABSTRACT
The work presented in this article, contribut to the improvement of methods of modeling unsaturated soil, and more specifically the study of the influence of the presence of chemical substance on the overall mechanical behavior of soils. To this end, we conducted in laboratory a series of permeation oedometric tests with loading various, on the clay and in the presence of chemical contamination. The ground deformations are a function of mechanical stress, suction (non saturation) and the mass concentration of the contaminant. This work thus allows us to answer the following questions: (i) What is the influence of mechanical loading on the change in concentration by the effect of consolidation? (ii)What is the influence of the chemical on the mechanical properties?

Keywords: behavior law, saturated soil, unsaturated soil, contamination, model, modeling

1. INTRODUCTION

In any geotechnical investigation, modeling is a critical step that determines the quality of analysis of diagnosis or prediction of the behavior of soils and structures. A model is not only a series of equations representing the physical behavior, mechanical, chemical soil is also a geometric representation of space, which defines the layers or volumes occupied by each material and specifies the place boundary conditions and interfaces, with their contact conditions. The model used in this work concerns the measurement of volumetric strain as a function of stress and of the chemical on the law of the mechanical behavior of clay. The development of constitutive equations based both on theoretical models of continuum mechanics (elasticity, plasticity, viscosity, and combinations thereof) and the results of experimental studies in laboratory and in place. We can obtain either very complex laws that seek to reproduce the smallest fluctuations in the experimental curves, or simpler models that are limited to the representation of key aspects of the behavior of real soils. To this end we will seek to establish a relationship between the likely behaviors of a chemical on the overall behavior through a simple model constructed from the experimental test plotting of a chemical, in accordance with a experimental dedicated protocol. We allow monitoring and analysis of migration of a chemical through a clay soil under controlled loading. Subsequently we derive conclusions can be drawn from the test results obtained in the laboratory.

2. METHOD AND TESTS

First, we begin by identifying the intrinsic characteristics of the soil. This identification requires the determination of physical, mechanical, all the identifications tests and perform according to the AFNOR. The objective of this identification is twofold, first the classification of soil type (clay) used for the experiment, and secondly the establishment of the behavioral relationship between the action of a mechanical efforts and chemical product. The soil that we used in our experimental work, has been withdrawn or the level of a cored geotechnical survey, when performing a geotechnical investigation of a housing project.

2.2 Testing of chemical tracing

The purpose of this part is the implementation of a experimental protocol allowing setting up of a relationship between the variation of the concentration of a chemical (ethanol) as a function of depth (height) of a sample of clay soil, one hand and the other by according the variation of the same concentration- change of the stress state exists inside the sample (tracing test). The experiment protocol developed consists in subjecting a clay soil with proper physical and mechanical identification (Table 1), a series of oedometric test with unsatureted conditions. We will search the state of chemical concentration emitted by a source of continued concentration over time (t = 500s, 1000s, 4000s, 10 000s, 100 000s, 400 000s) and space (y = 4mm, 8mm, 12mm , 16mm, 20mm) under various loading (σ_v =10Kpa, 100Kpa) Figure1.

Table 1. Physical-mechanical characteristics of the soil

Argile de Numidie	γ_d g/cm^3	γ_h g/cm^3	W %	S_r %	$\%80\mu m$ %	P_c bar	C_t %	C_g %	C_{uu} bar	φ_{uu} (°)
	1.60	1.94	18.0	70.6	82	1.04	18.2	5.04	0.30	16.0

γ_d : dry density ; γ_h : wet density ; w : water content ; S_r : degree of saturation ; $\%80\mu m$: 80µm sieve ; P_c : pre consolidation stress ; C_t : coefficient of compaction ; C_g : Swelling coefficient ; C_{uu} : unconsolidated undrained cohesion ; φ_{uu} : internal friction angle, undrained unconsolidated

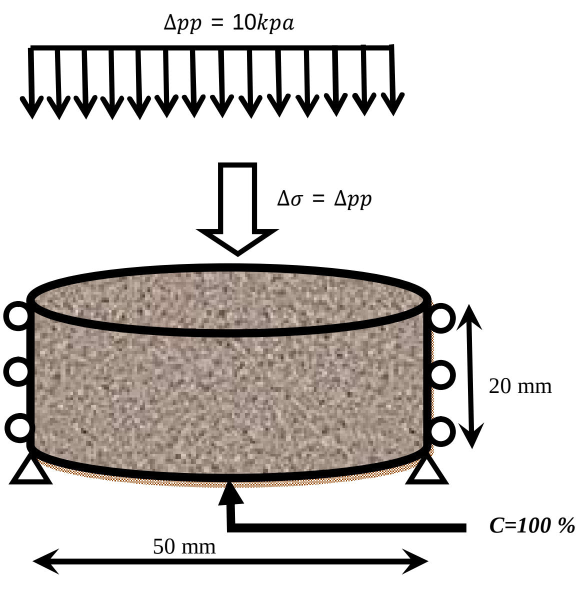

Figure.1 Diagram of the experimental test with the introduction of chemical contamination from the bottom.

2.3 Equipment used

For the purpose of the experimental protocol we used: a beaker, Mantic shaker, glass test tubes, Volumetric flask, Balance high precision d=0.0001g, Chronometer, Wash bottle, Spatula, Funnel, Oedometric cell for permeability test, Burette with tap, Filter paper, Sieve 0.02mm, Gas chromatography (GC)

2.3.1 Procedure

1 / Preparation of chemical concentration used:
Dose 20 ml of ethanol in one liter of distilled water, stirring a few minutes in a magnetic stirrer.

2 / Preparation of soil sample and procedure of test:

1. Install an intact soil sample, in the oedometric cell and seal,
2. Pipette the concentration prepared in the burette to a height well determined (depending on the load piezometric wanted, in our case $\Delta pp = 10Kpa$)
3. List the arm of the odometer with a weight to obtain the desired vertical stress (in our case: 10 and 100 kPa)
4. Open the valve, and comes that the piezometric head is constant,
5. Turn off the tap of the burette, after a time t = 500s,
6. Take of soil samples throughout the thickness of the sample to 4 mm apart,
7. Solubilized samples from an inert solution in water-based distilled (in 20 ml) for determination in the GC,

Repeat the procedure 1 to 3 with different times (1000s, 4000s, 10000s, 100000s, 400000s) for a constant temperature and a constant vertical stress.

2.3.2 Assays of ethanol by gas chromatography (GC)

2.3.2.1 Principle and procedure of the test

The dosage is based on the physicochemical properties following: the hydro solubility and volatility. We dissolved the ethanol present in the soil by mixing it with 20ml of distilled water. As a result we made the determination by gas chromatography with a FID detector by injecting 10µl against a calibration curve according to the OSHA technique.

3. RESULTS OF THE TEST TRACING

The figures that follow represent the results of analysis performed by GC, she shows the variation of the concentration of ethanol according to the variation of the height and time, according to a well-known stress state.

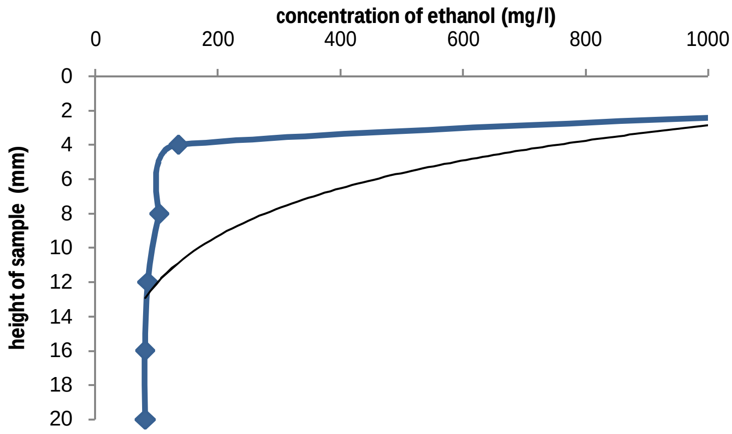

Figure2. Determination of ethanol for t = 500s and stress σ_v =10 kpa

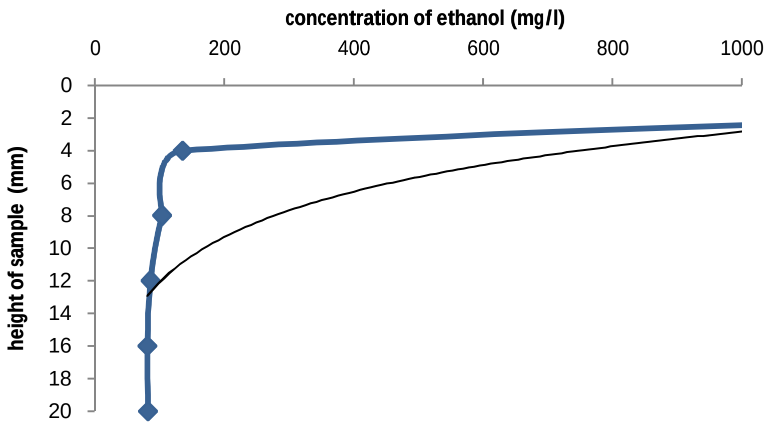

Figure3. Determination of ethanol for t = 1000s and stress σ_v =10 kpa

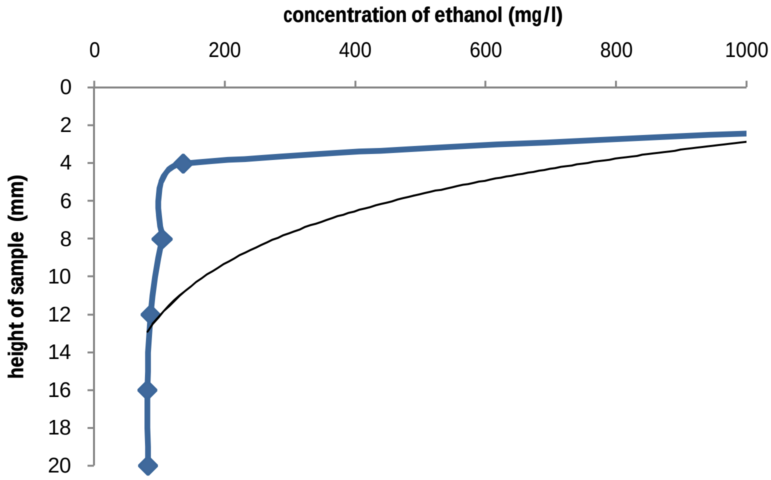

Figure4. Determination of ethanol for t = 4000s and stress σ_v =10 kpa

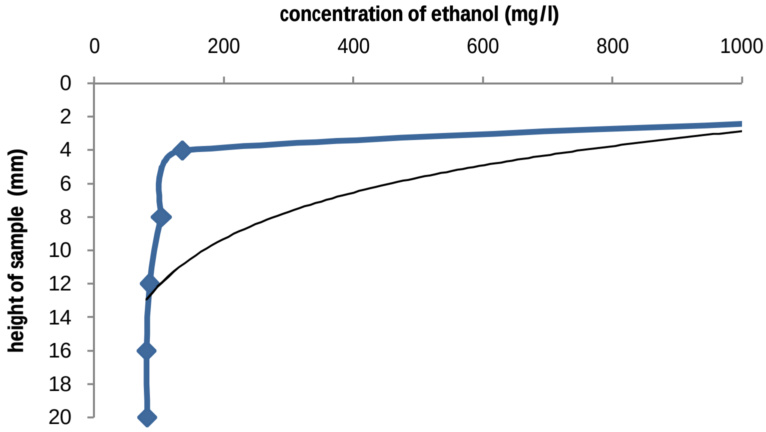

Figure5. Determination of ethanol for t = 10000s and stress σ_v =10 kpa

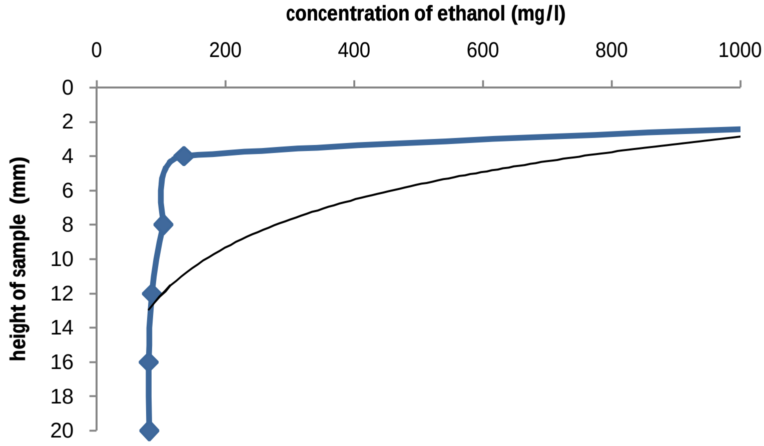

Figure6. Determination of ethanol for t = 100000s and stress σ_v =10 kpa

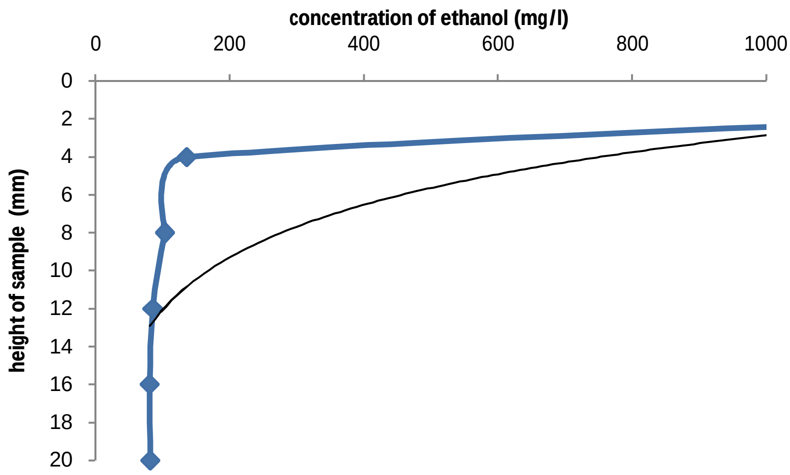

Figure7. Determination of ethanol for t = 400000s and stress σ_v =10 kpa

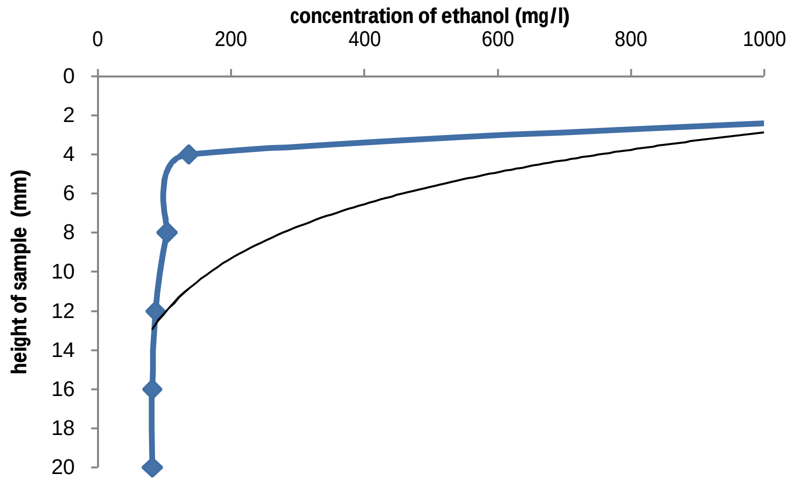

Figure 8. Determination of ethanol for t = 100s and stress σ_v =100 kpa

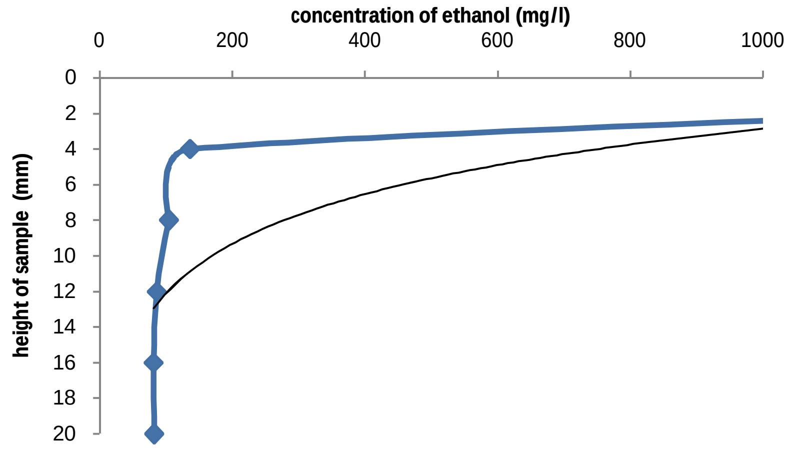

Figure9. Determination of ethanol for t = 1000s and stress σ_v =100 kpa

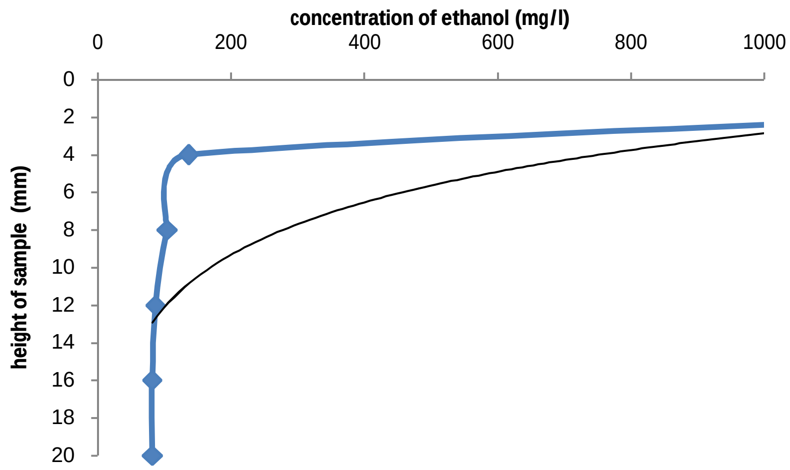

Figure10. Determination of ethanol for t = 400000s and stress σ_v =100 kpa.

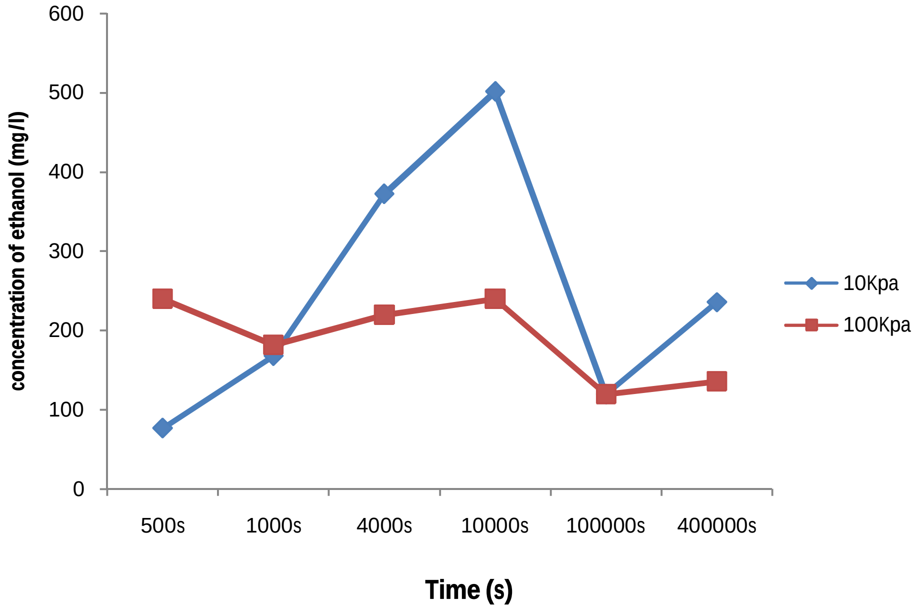

Figure11. Relationship between the variation of the concentration versus time, for y = 4mm

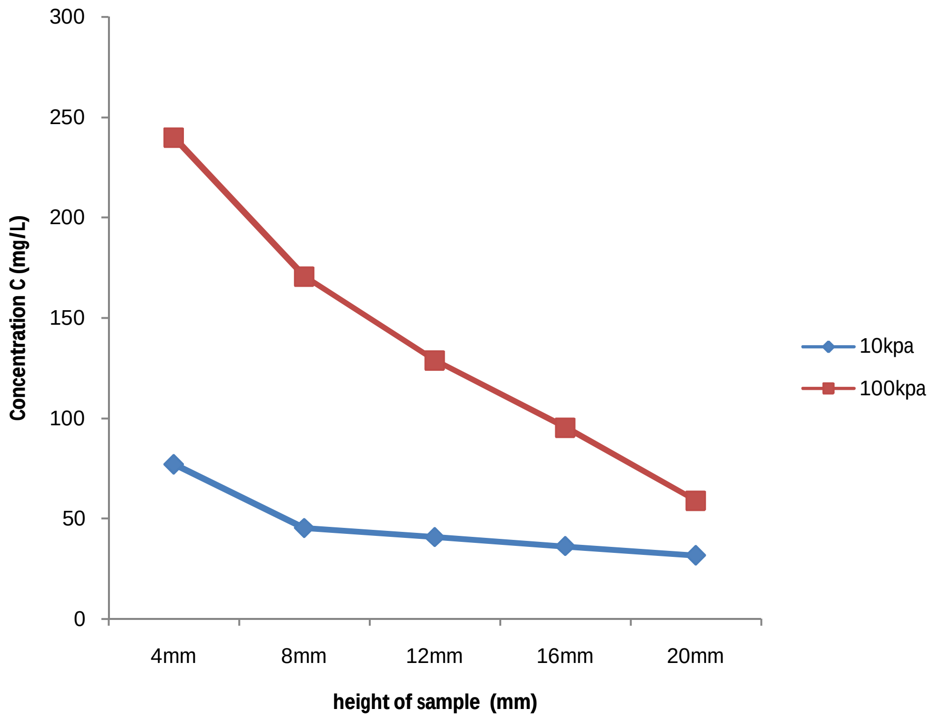

Figure 12. Relationship between the change in concentration as a function of height, for t=500s

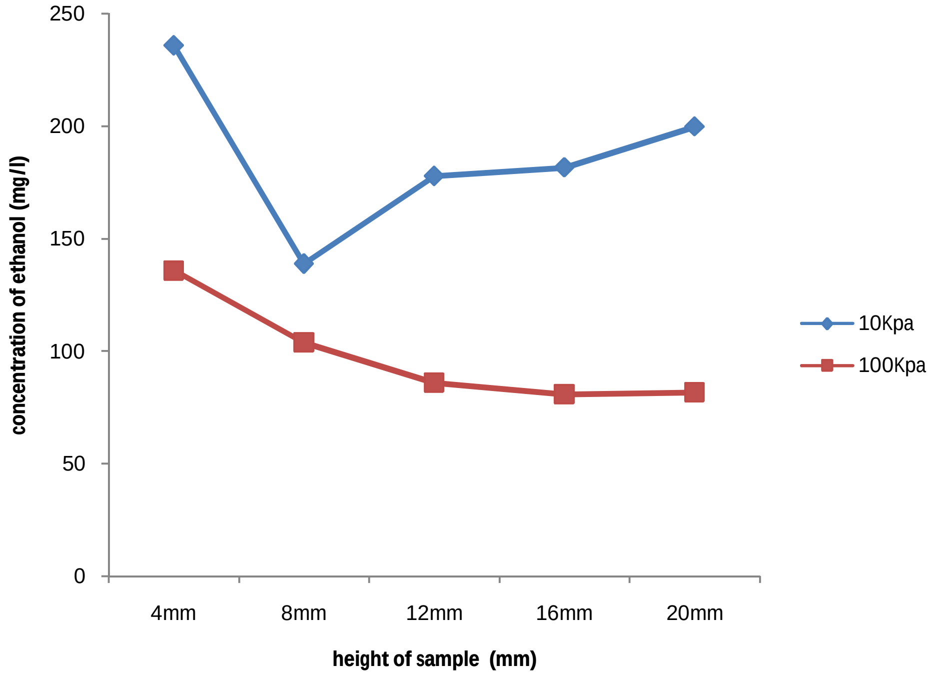

Figure13. Relationship between the change in concentration as a function of height, for t = 400000s

4. DISCUSSIONS

From figures 2 to 10 we see first an increase in concentration over time, reflecting the immigration of pollution through the soil. The shape of the concentration curves (Figure 2 to 10) have a classical forms is predictable from the position of the source concentration (Coast 0.0), that is to say we have a maximal contamination for y = 0 followed by a decrease in the same concentration for (y = 4mm, 8mm, 12mm, 16mm, 20mm). The figure 12 shows the increase in concentration with increasing vertical stress, this increase is variable, in fact, and we note that the increase in concentration is significant near the source. By cons in areas far from the pollution source, we note that the influence of the increased mechanical load on the state of concentration is low. According to Figure 13 which shows the change in the concentration compared to the increased mechanical load with a time large enough for all the sample whole is contaminated, we see a phenomenon totally contrary to the observations given in Figure 12. Indeed Figure 13 shows that the value of the rate of concentration decreases, to increasing the vertical stress only. This leads us to postulate that:

Postulate (1): The increase in isotropic pressure in a clay soil polluted by a chemical causes the decrease in the concentration of that substance.

So we can from the postulate 1, schematically define the relationship governing the variation of the concentration according to the variation of mechanical loading:

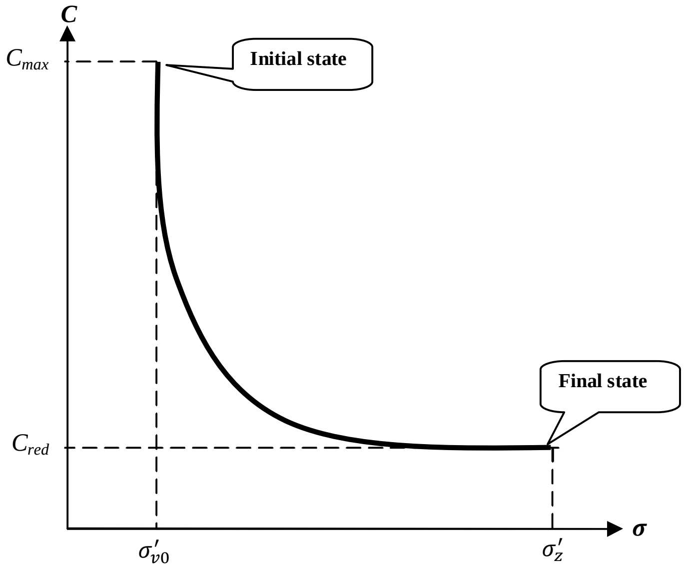

Figure14. Pattern of chemo-mechanical relationship

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with:
Cmax : Initially and maximum concentration.
Cred : Residual concentration (minimum).
σ'_{v0} *:* Initial effective stress.
σ'_Z *:* Maximum effective stress.

4. CONCLUSION

The experimental study devoted to the development of a chemo-mechanical model of clay in the laboratory, was successful. Thus we have succeeded in developing a experimental protocol dedicated. After the physical and mechanical identification tests carried out on clay, we conduct a tracing chemical test under unsaturation condition and under the action of a variable mechanical load, through a permeation device oedometric. The results obtained have allowed postulated that the increase in isotropic pressure in a clay soil polluted by a chemical causes a decrease in the concentration of that substance.

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